More material for P5

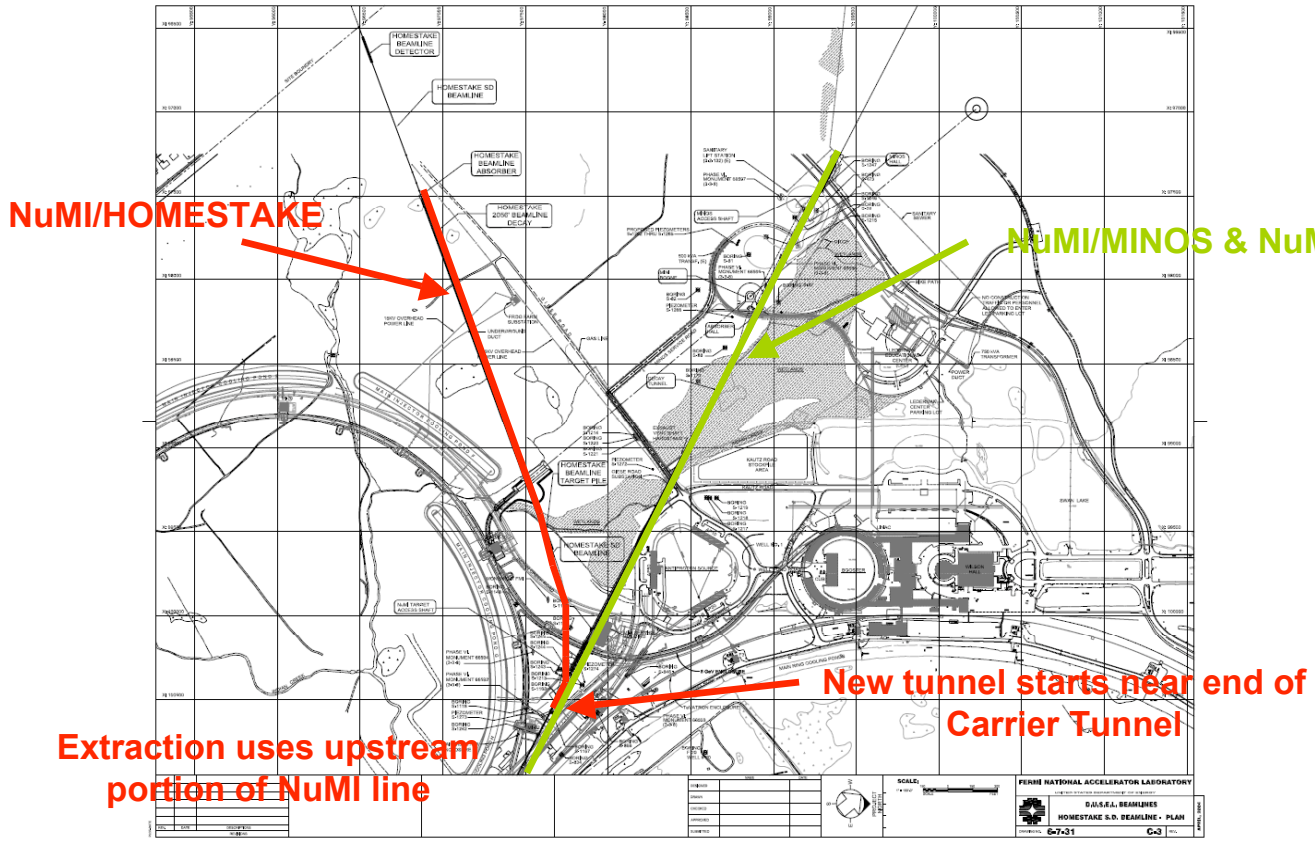
Milind Diwan for the
Homestake neutrino
detector group
3/1/2008

Comments

- All rates calculated with full GEANT simulation with same computer code by same person. Later checked by others and compared to MINOS data rate. Code is GNuMI.
- For NuMI/Homestake the simulation geometry is modified. Everything is documented in the Study. http://nwg.phy.bnl.gov/fnal-bnl
- For NuMI/Homestake the design is not final and not completely optimized. Assume 25% accuracy.
- Only as examples, we have chosen to calculate the sensitivities with two scenarios: a beam using
  - A) 60 GeV protons at 0 deg angle.
  - B) 120 GeV protons with a 0.5 deg off-axis angle.
- 1 yr ~ 2×10^7 sec for all FNAL neutrino running.

Beam line length

For details
http://nwg.phy.bnl.gov/~diwan/300kt/public/meetings/oct12-2007/D.Bogert.101207.ppt



Homestake/DUSEL Neutrino Beam

Ref: Dixon Bogert

- There is adequate space for a decay tunnel of 627 m
- We are using decay tunnel of 380 m in simulations.

Raw event rates
1 MW for 3 yrs at 120 GeV

Ref: Tables IV and VI in study. Same osc parameters

type	Homestake with 100kT	NOvA with 15 kT
Numu CC no osc	53940	7245
Numu CC with osc	22740	2880
Nue CC $\sin^2 2\theta_{13} = 0.04$	972	119

With120 GeV 0.5 deg beam.

With120 GeV medium energy tune.

Near detector

- There will be a near detector for the NuMI/Homestake beam line.
- There are many choices: as an example, the HiRESMnu (Ref: Misra) design is costed to be ~$13M. This cost should be part of the beam line cost. A 1 ton liquid argon TPC is also a possibility.
- Several of the proponents are experts at this analysis from other experiments. We assert that a high resolution near detector is far more than adequate for our purposes. The event rate will be ~1/ton/10μsec pulse. This can be handled by any modern system.

Near detector

- With no near detector ~10% error on background has been achieved by many experiments going back to the 1980s. This is sufficient for mass hierarchy determination with 100kT.
- The goal of achieving 5% uncertainty on the background is achievable with a high resolution near detector such as the HiRESMnu or a 1 ton LAr TPC. This improves sensitivity to CPV with 100kT.
- The systematic requirement is easier in an experiment where a precise oscillatory shape in energy is expected. This is impossible in a narrow band beam.
- Systematics of an off axis beam is difficult due to the difficulty in locating the near detector such that it samples the same beam.

$\sin^2 2\theta_{13}$= 0.04, 100kT, 1300 km, ~1 MW 120 GeV (0.5deg)

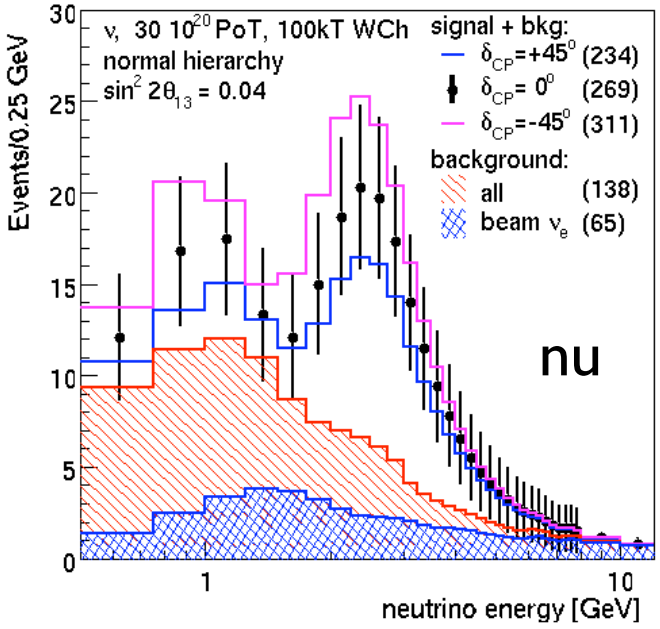
3yrs neutrinos, 3yrs antineutrinos

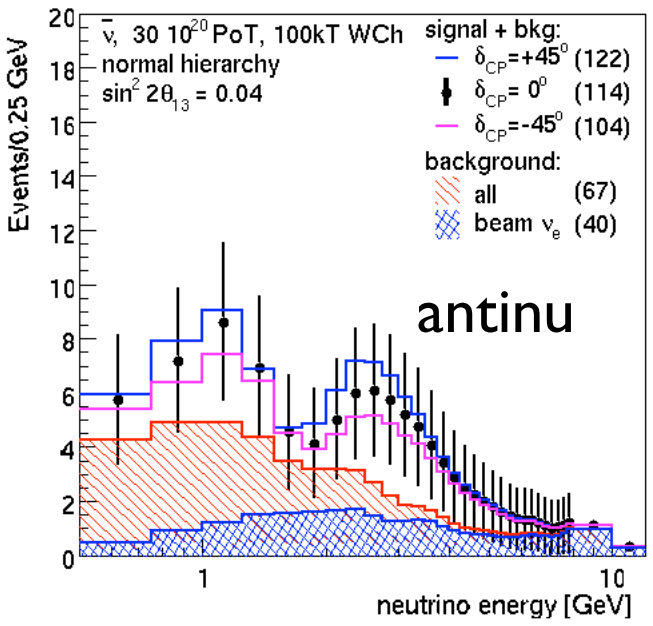
$(-\delta_{cp} = -45°, -\delta_{cp} = +45°)$

Spectra with 100 kT detector and 1 MW beam from FNAL

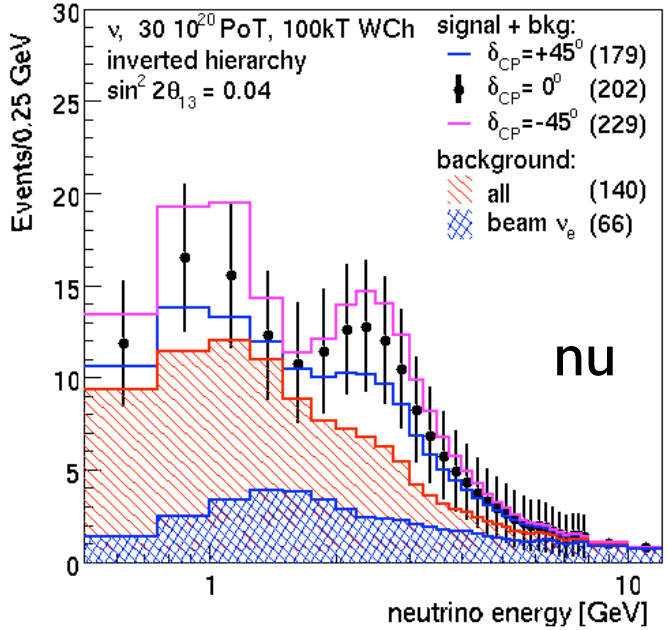
Total rate of CC neutrino events ~18k/MW/yr noosc/raw evts

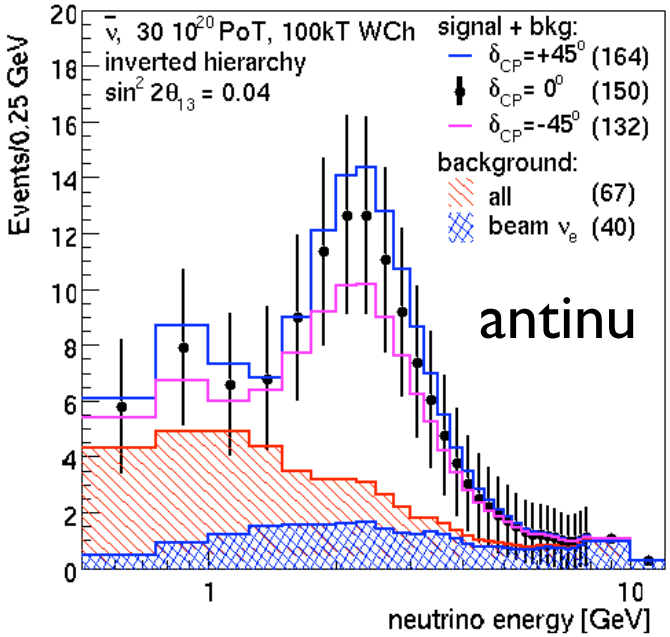
Normal





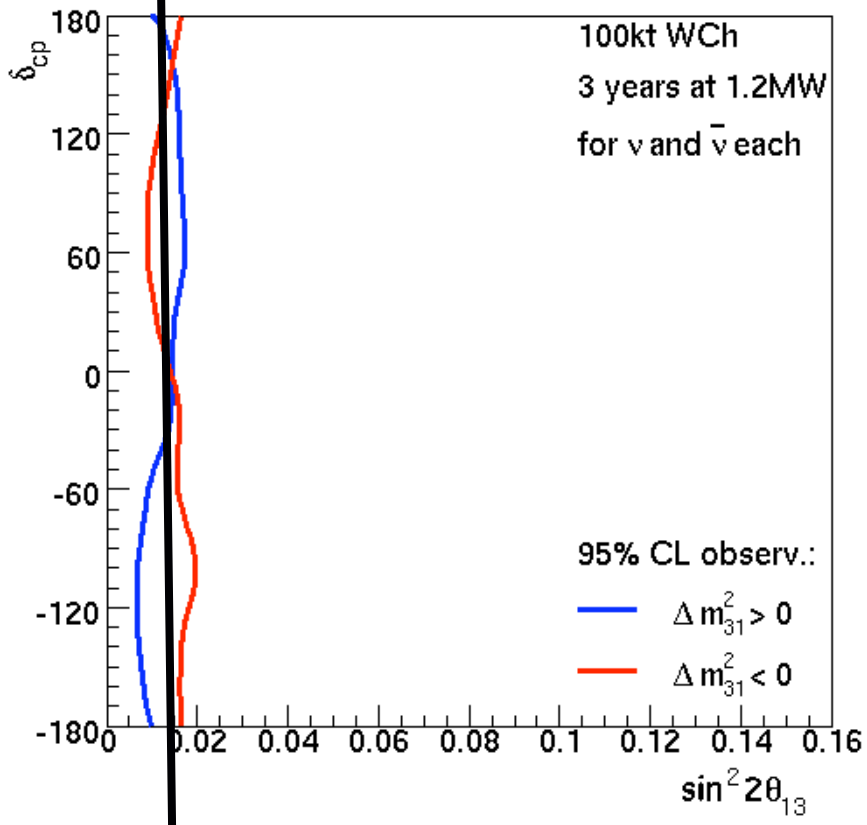
Reversed





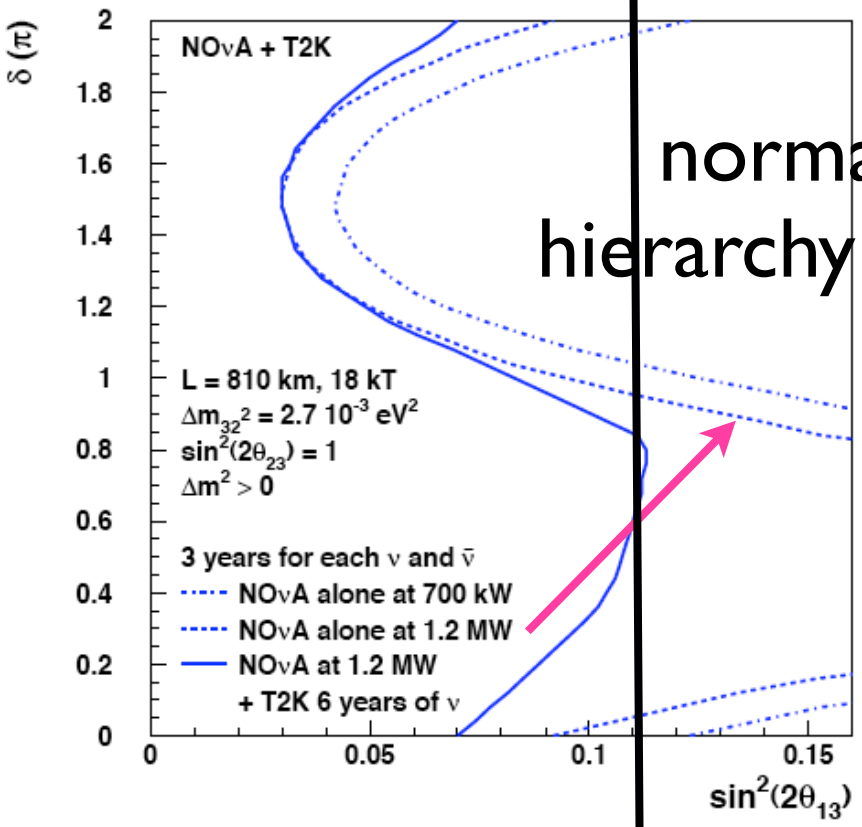
Mass hierarchy sensitivity

Homestake
100kT



0.015

NOvA
(18kT)



normal
hierarchy only

0.11

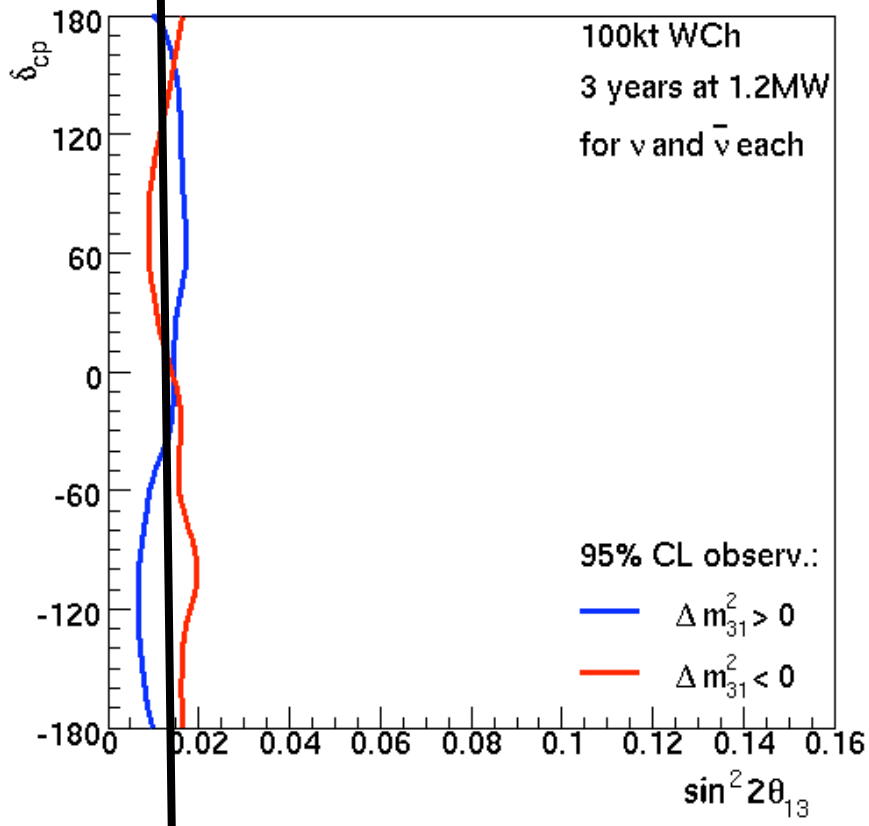
95 % C.L.

ref:NuFact07

The homestake project is almost an order of magnitude better for mass hierarchy determination for same running

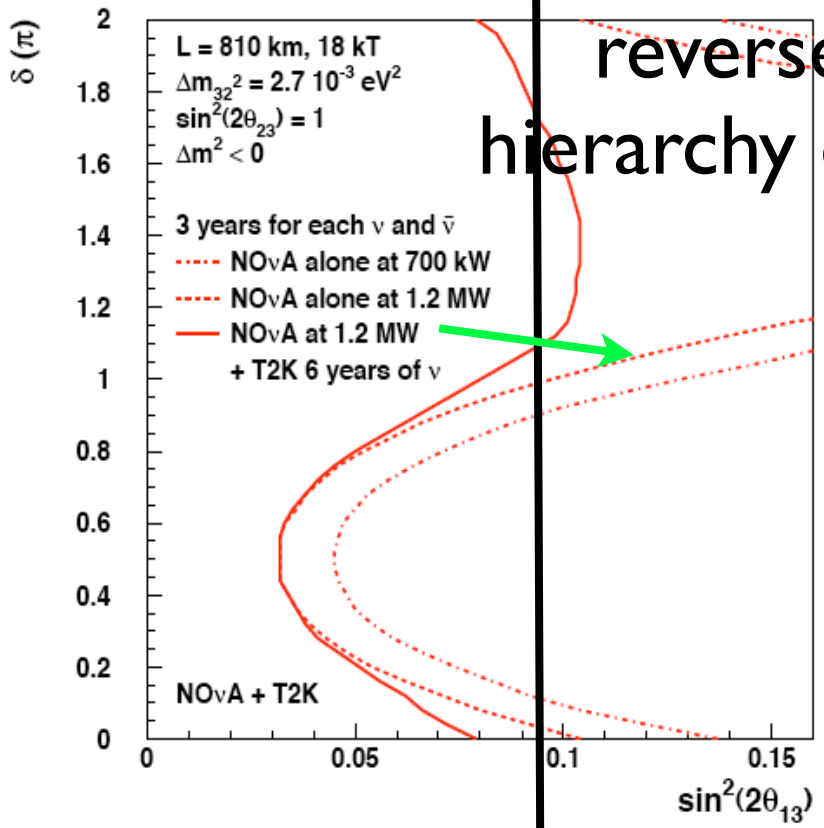
Mass hierarchy sensitivity

Homestake
100kT



0.015

NOvA
(18kT)



reverse hierarchy only

0.11

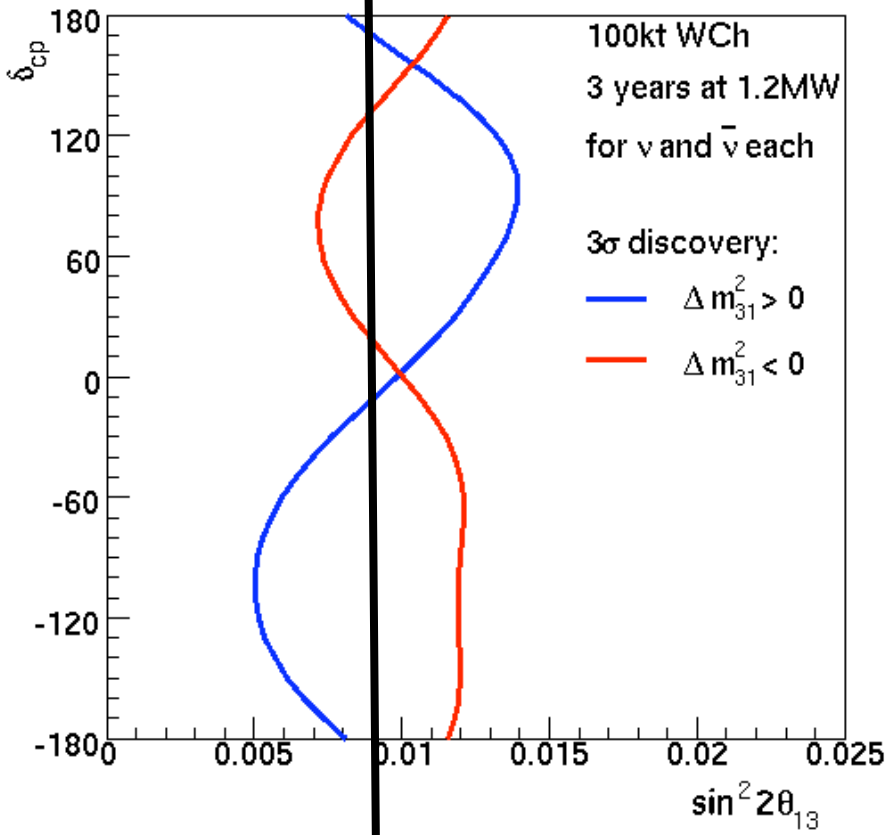
95 % C.L.

ref:NuFact07

The homestake project is almost an order of magnitude better for mass hierarchy determination for same running

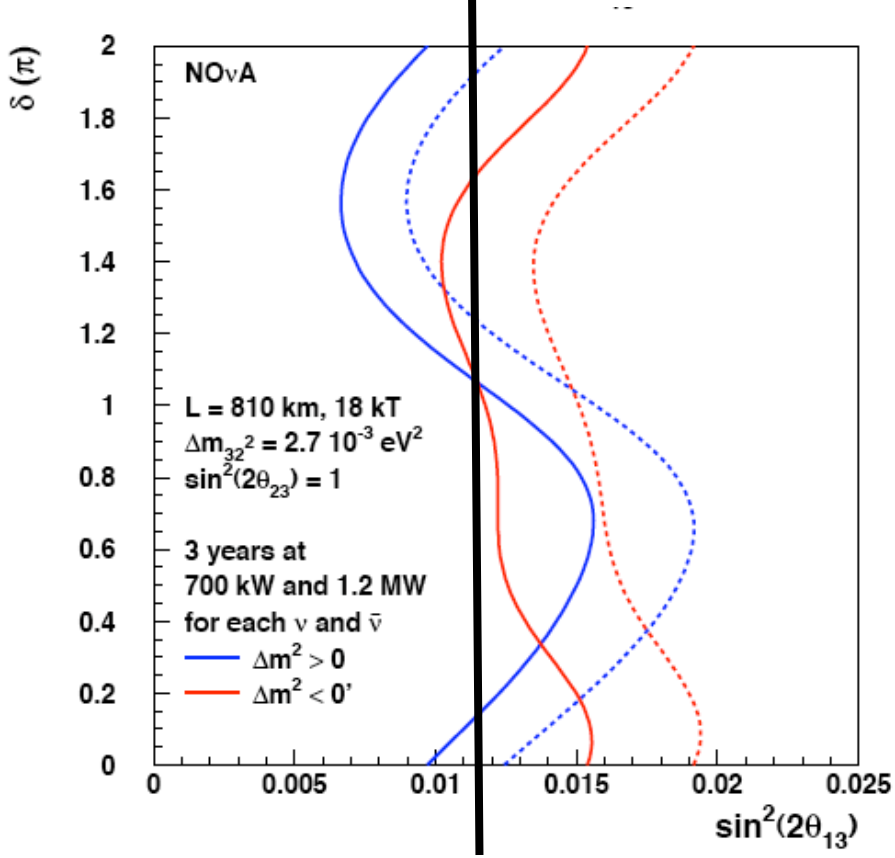
Sensitivity to $\mathrm{Sin}^2 2\theta_{13}$

Homestake
100kT



0.009

NOvA
(18kT)



0.012

3 sigma

ref:NuFact07

Value of $\sin^2 2\theta_{13}$ for 50% coverage in CP phase

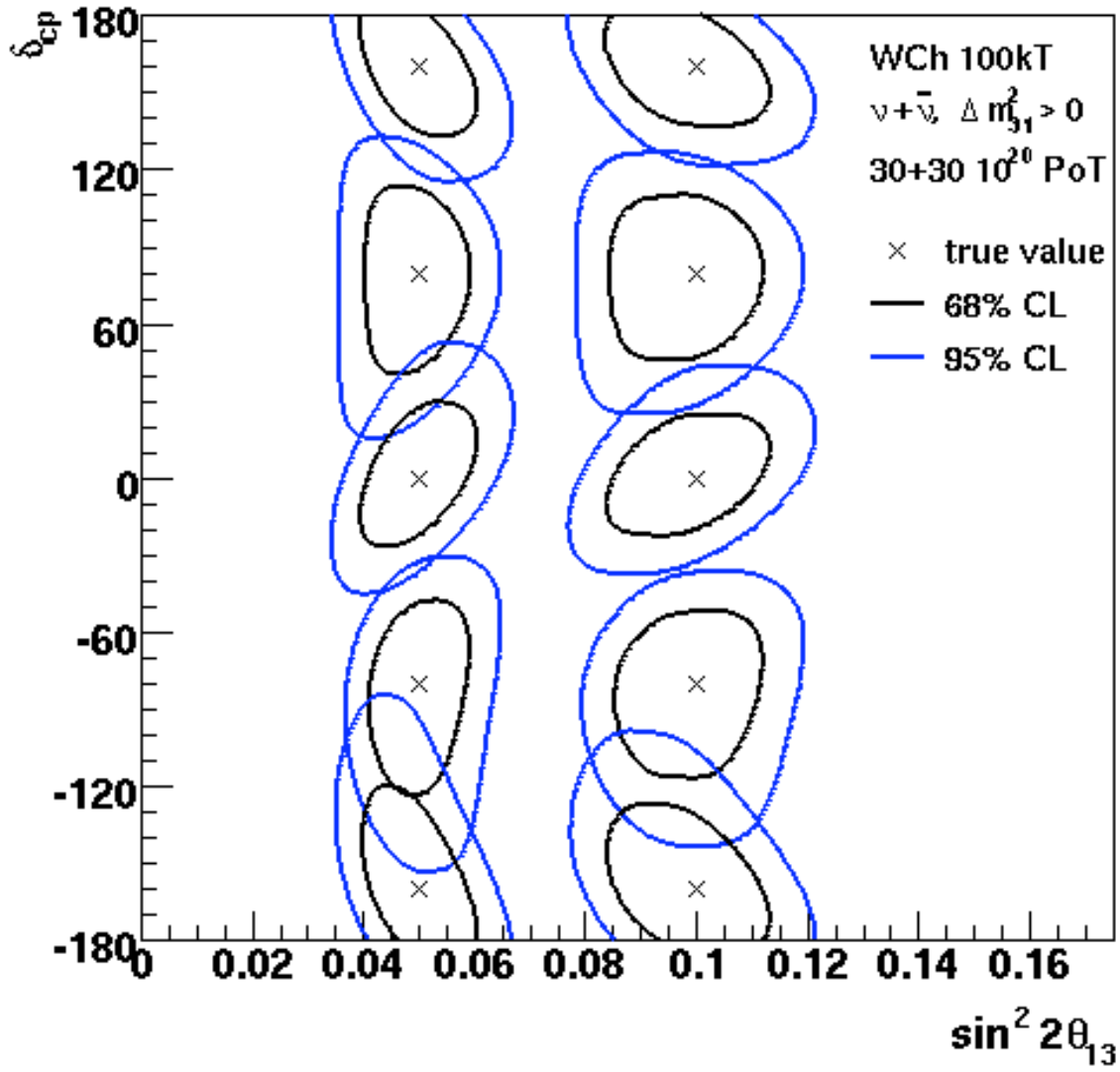
	Homestake 100kT	NOvA 18kT
Mass hierarchy	0.015	0.11
$\sin^2 2\theta_{13}$	0.009	0.012

Running conditions: 120 GeV, 1 MW for 3 yrs nu and 3yrs antinu

The homestake project is almost an order of magnitude better for mass hierarchy determination for same running

Measurement of CP with 100kT water Cherenkov at Homestake

There are no ambiguities for each of these test cases with test points at the X



The Homestake project can lead to early CP violation indications.

Credits

- This is a partial list of young people who have worked on the very long baseline project since 2001. There are many papers and detailed calculations.

Christine Lewis(Columbia)★
Jordan Heim (Purdue)
Bob Davis (Colorado)
Brett Viren(Stonybrook/BNL)
Mark Dierckxsens (UChicago, BNL)
Mary Bishai (BNL)
Fanny Dufour (Boston University)
P.T. Le (StonyBrook)
Patrick Huber (Wisconsin)
Danny Marfatia (Kansas)
Robert Zwaska (FNAL)

In addition, credit goes to

Chiaki Yanagisawa(StonyBrook)
Ed Kearns(Boston U) and
SuperK collaboration
for help with simulations.

Many others who participated in the FNAL/BNL study

★ Undergraduates

Conclusion

- NOvA has only a 50% chance of getting information on the mass hierarchy for large values of $\sin^2 2\theta_{13}$ near the current bound. This capability could diminish very quickly as the bound improves.
- The Homestake 100kT water Cherenkov detector gives 100% guarantee for the mass hierarchy for small $\sin^2 2\theta_{13}$. The statistics are large, and the effect is large.
- The Homestake 100 kT water Cherenkov detector is the first step towards a program with ≥300 kT fiducial mass for high precision CP violation and nucleon decay and neutrino astrophysics.